After Effects of Welding Armor Steels

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Matt Rogers

Welding Engineer

TARDEC

RDTA-EN/ Materials/Environmental

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
31 AUG 2011	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
After Effects of Welding Armor Steels	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Matt Rogers	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA	**22261**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA	**TACOM/TARDEC/RDECOM**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) **22261**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

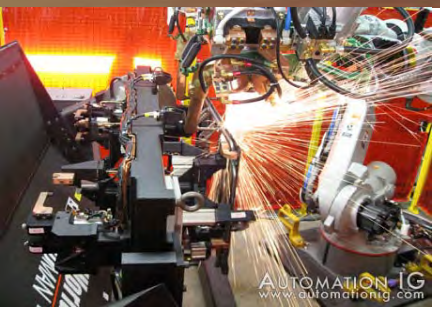
13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**25**	

Presenters:



Matt Rogers

Welding Engineer

- Dec 2009 Welding Engineer @ TARDEC
- Welding Engineer, 6 years Application Engineering experience
- Bachelors of Science in Welding Engineering Technology from Ferris State University
- Associates Degree in Welding Technology
- 14 years Welding Experience

Overview

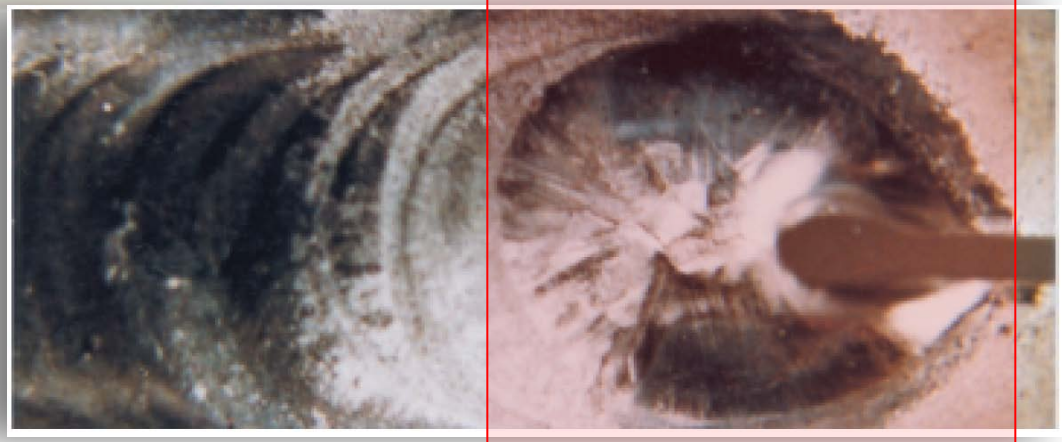
- Materials and Types for Cracking
  - Hot Cracking
  - Cold Cracking
- Types of cracks
- Causes
  - Hydrogen
  - Electrode Selection
  - Electrode Storage
- Inspection Methods
  - PT, UT, RT, MT
- Preventions
- Conclusion

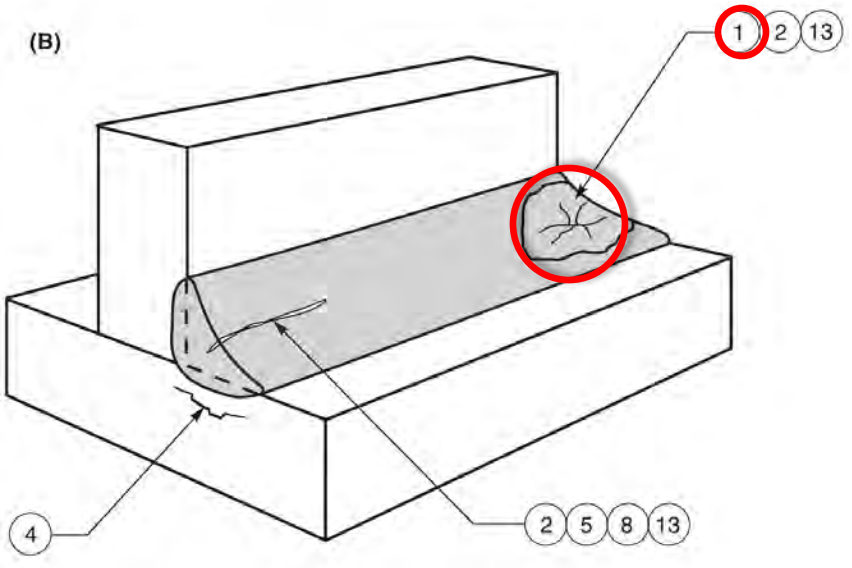
Materials/Cracks

- MIL-DTL-46100, MIL-DTL-12560J, & MIL-DTL-32332

- Hot Cracking
  - Definition: Cracks in the weld, which results from stress in the material during solidification of the pool

- Cold Cracking
  - Definition: Cracks in the weld, which occur after the weld has solidified and cooled to ambient temperatures.





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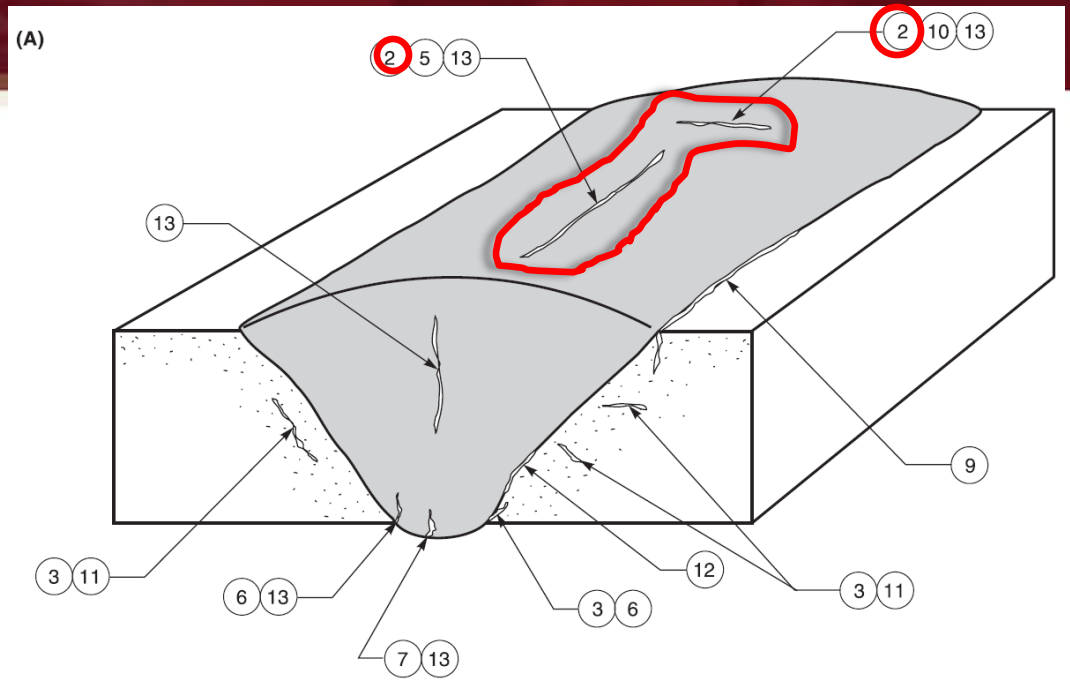

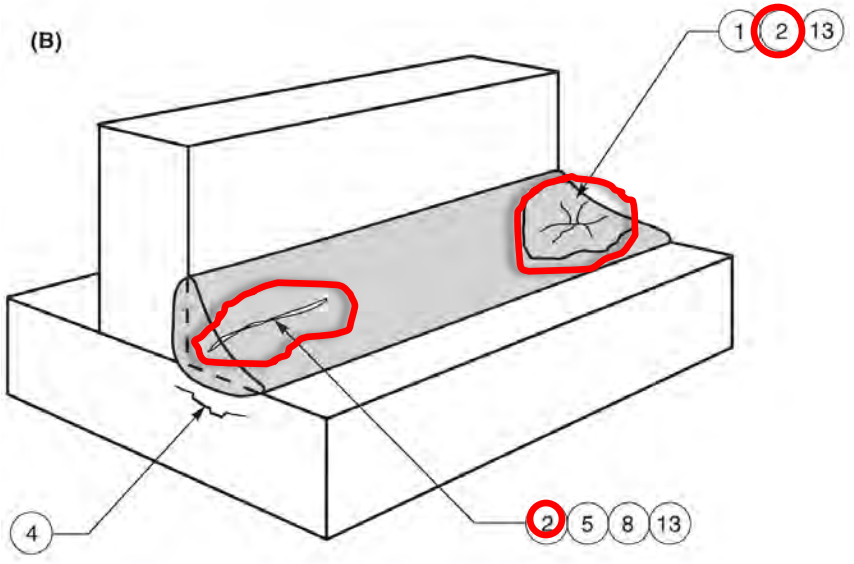

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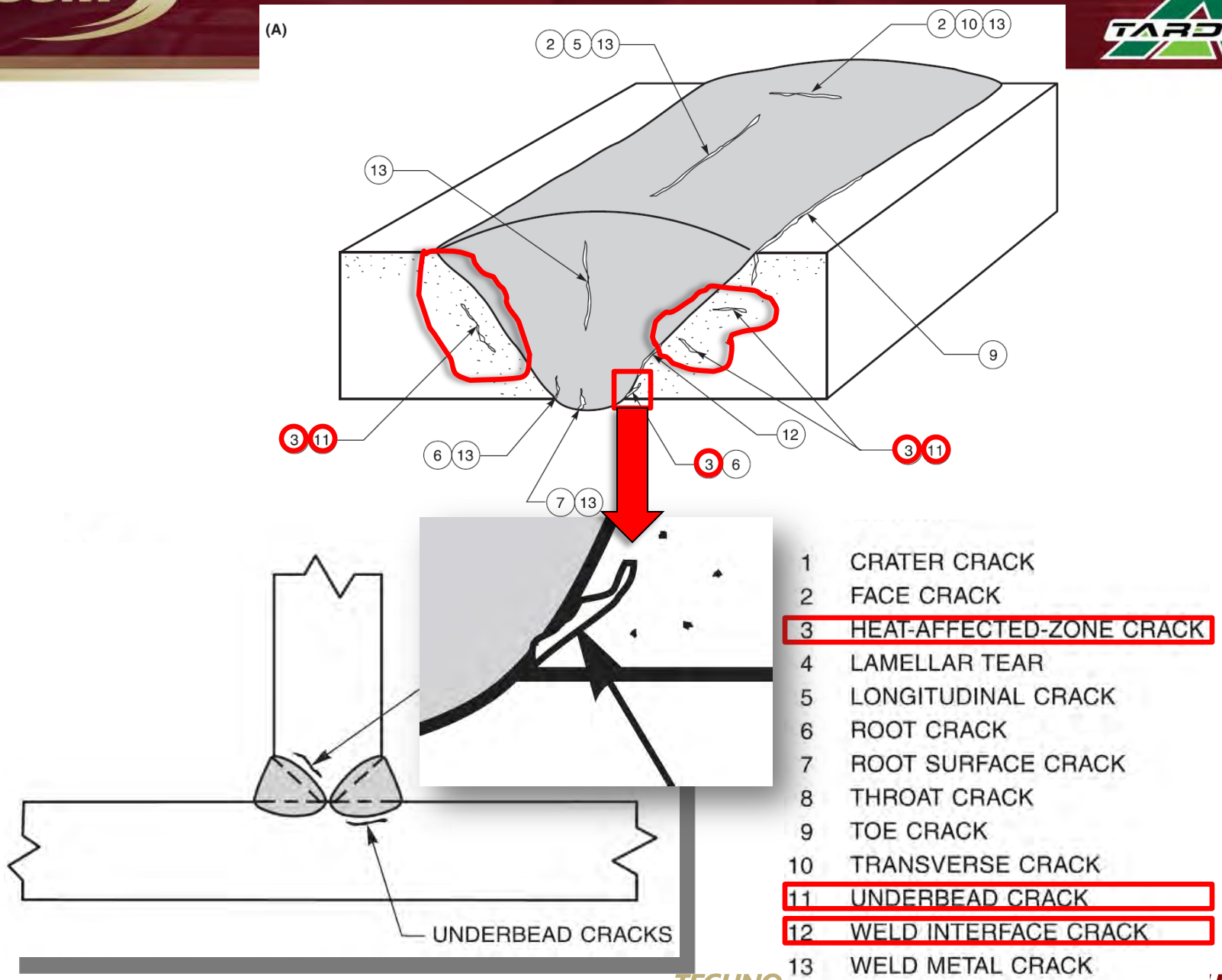

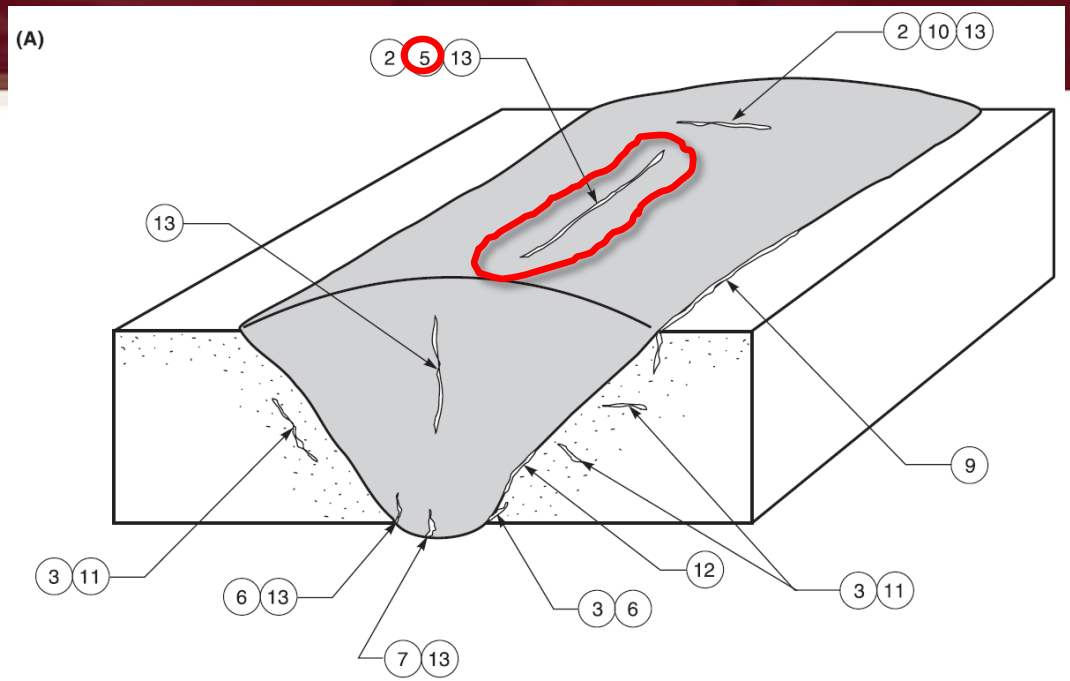

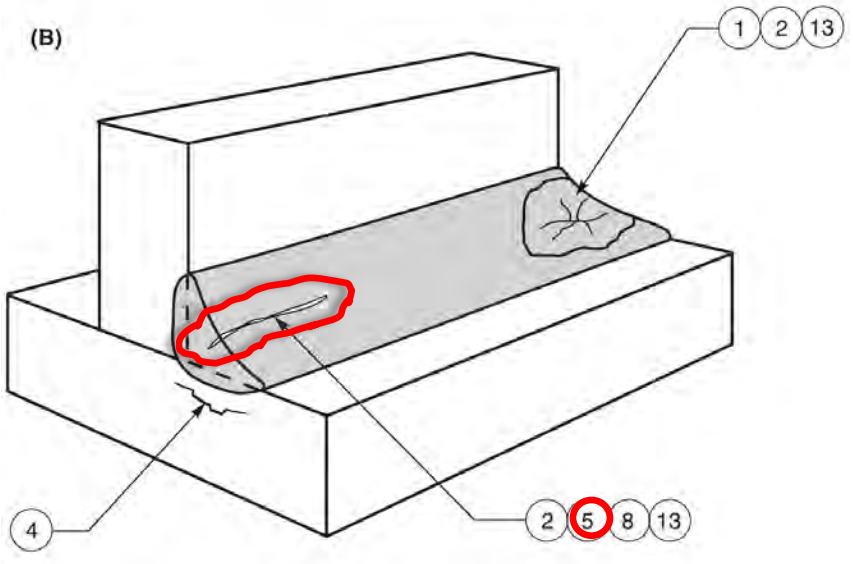

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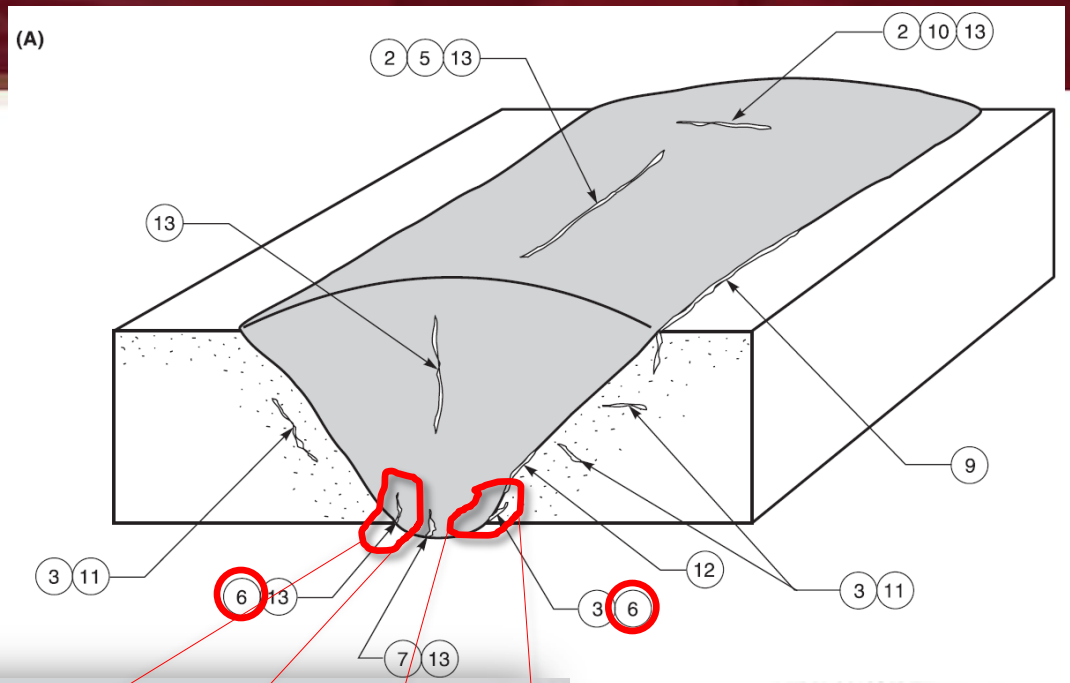

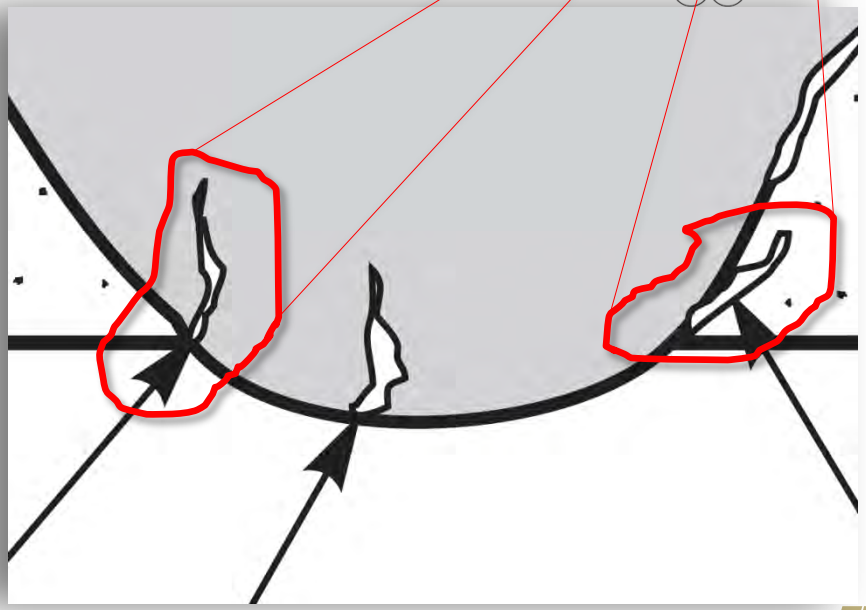

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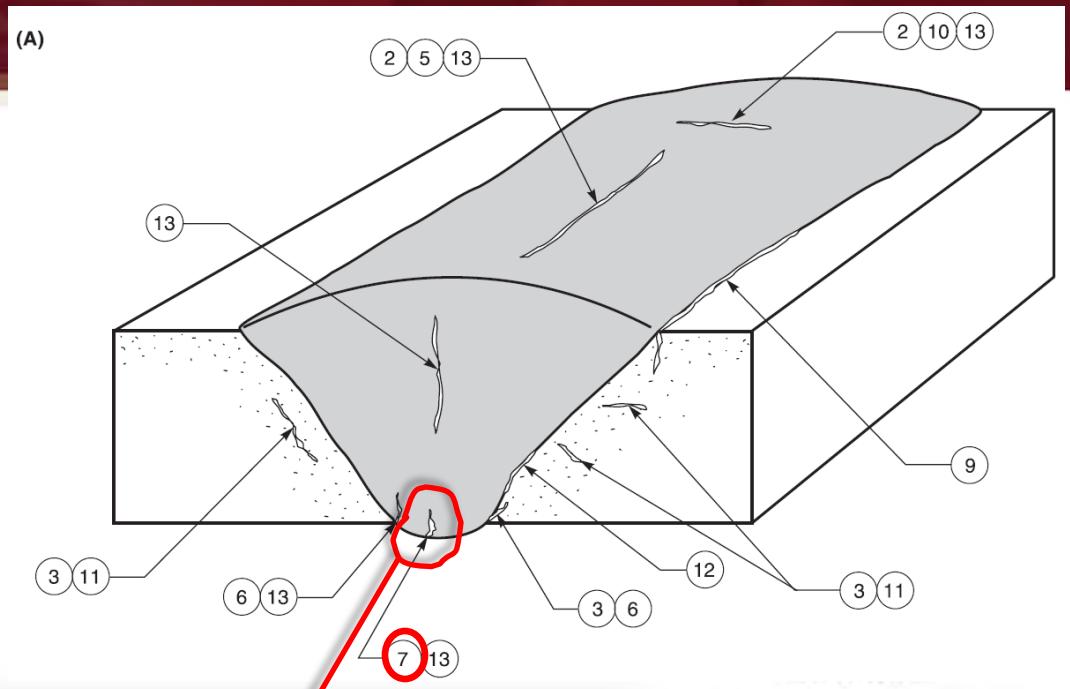

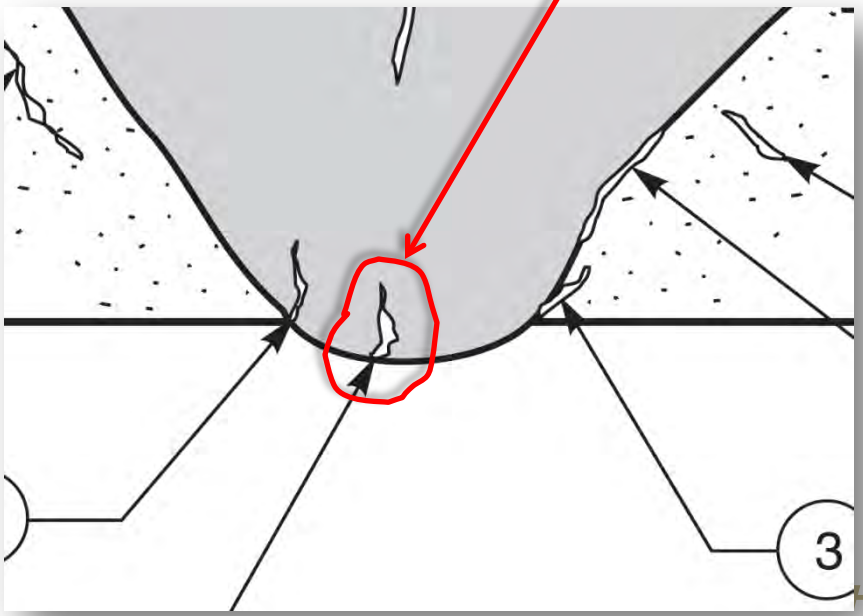

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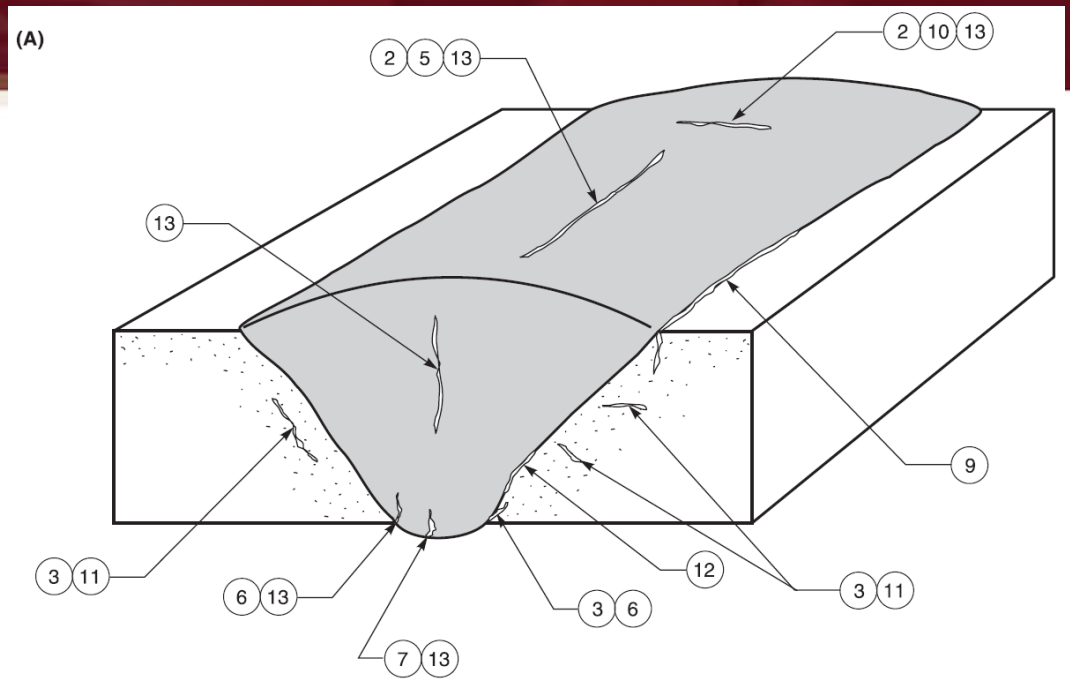

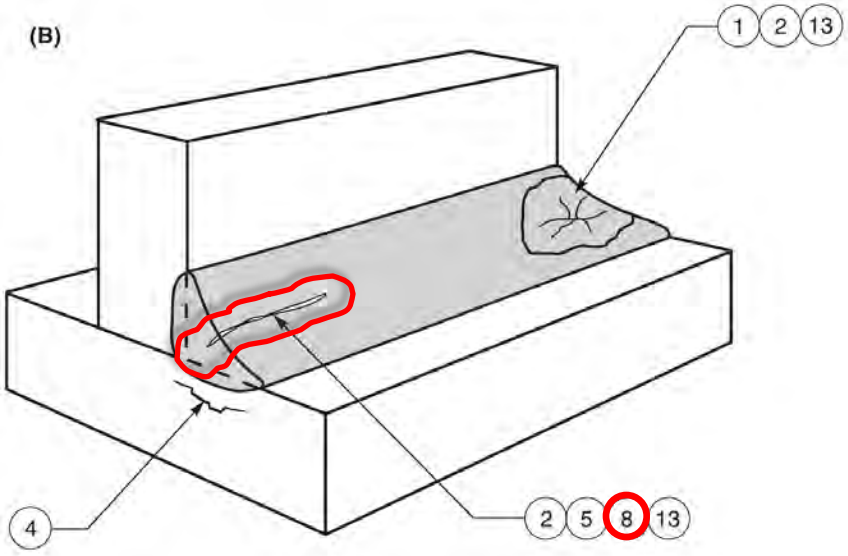

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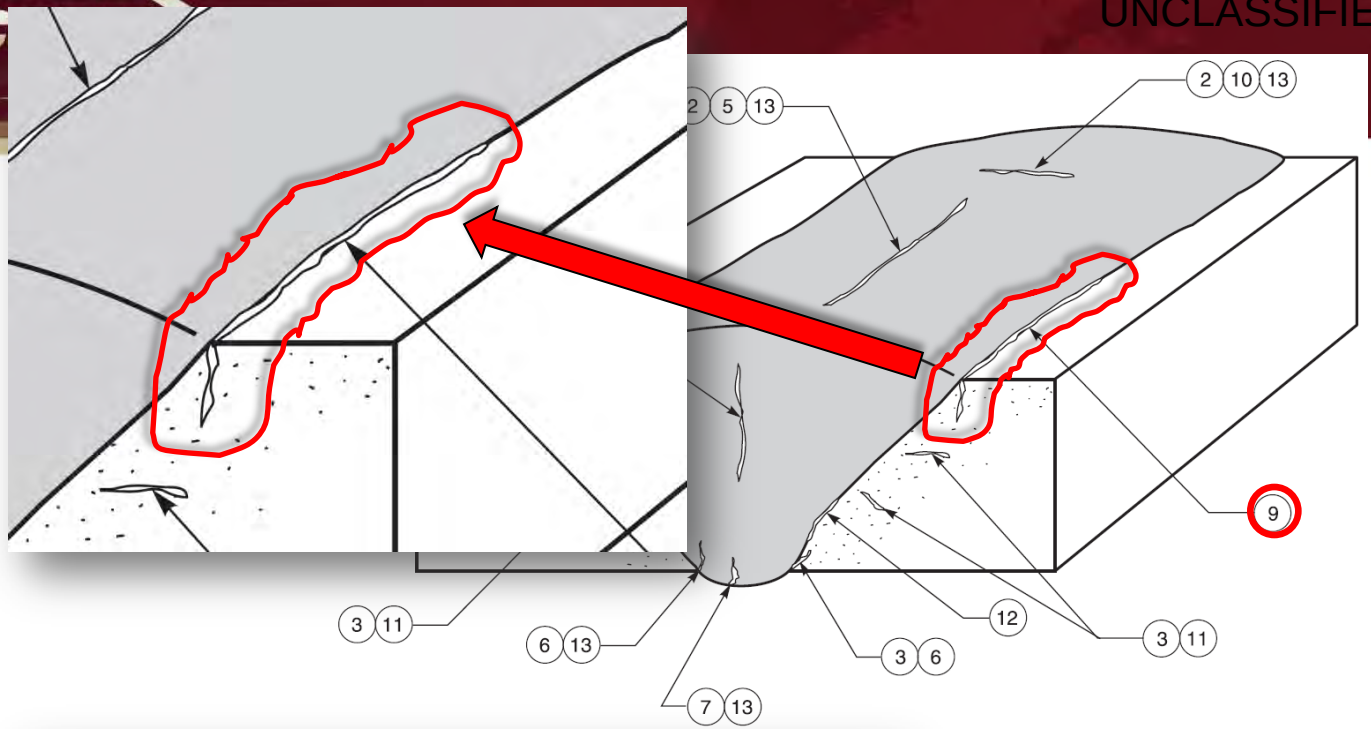

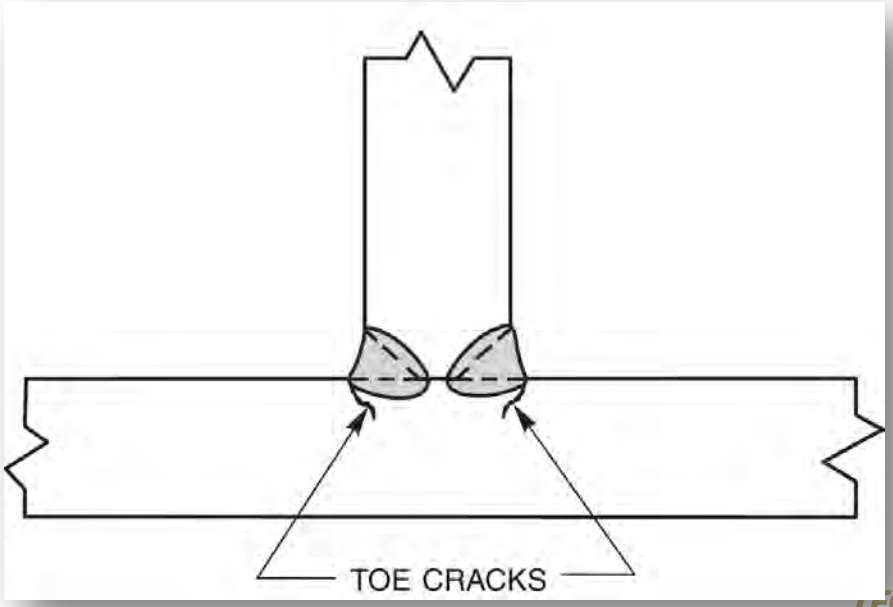

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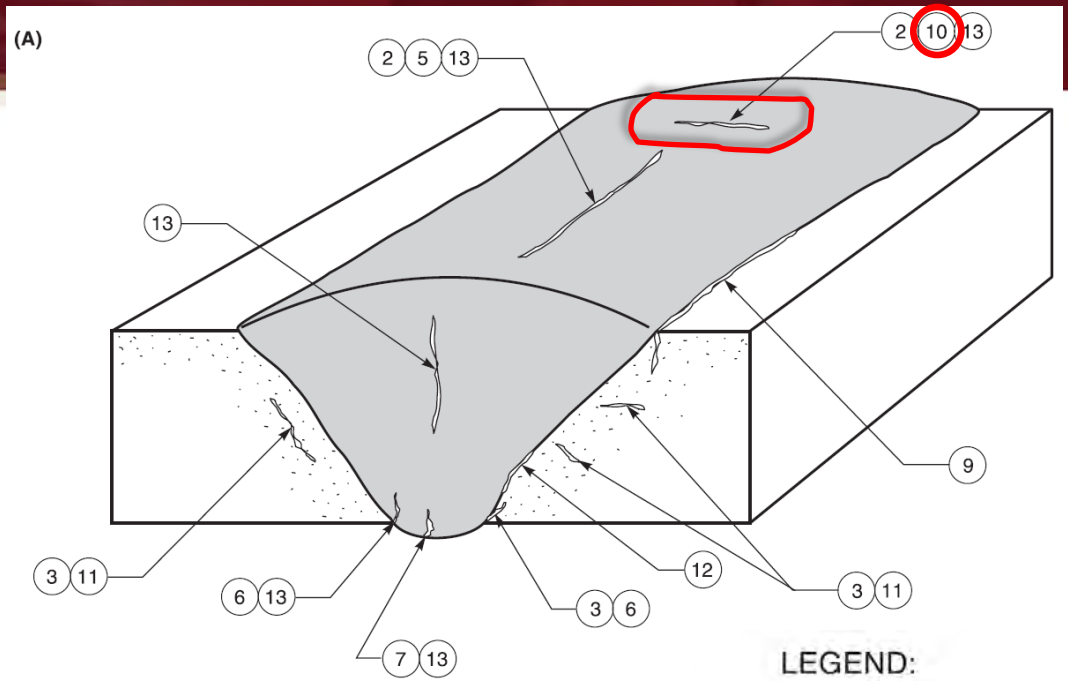

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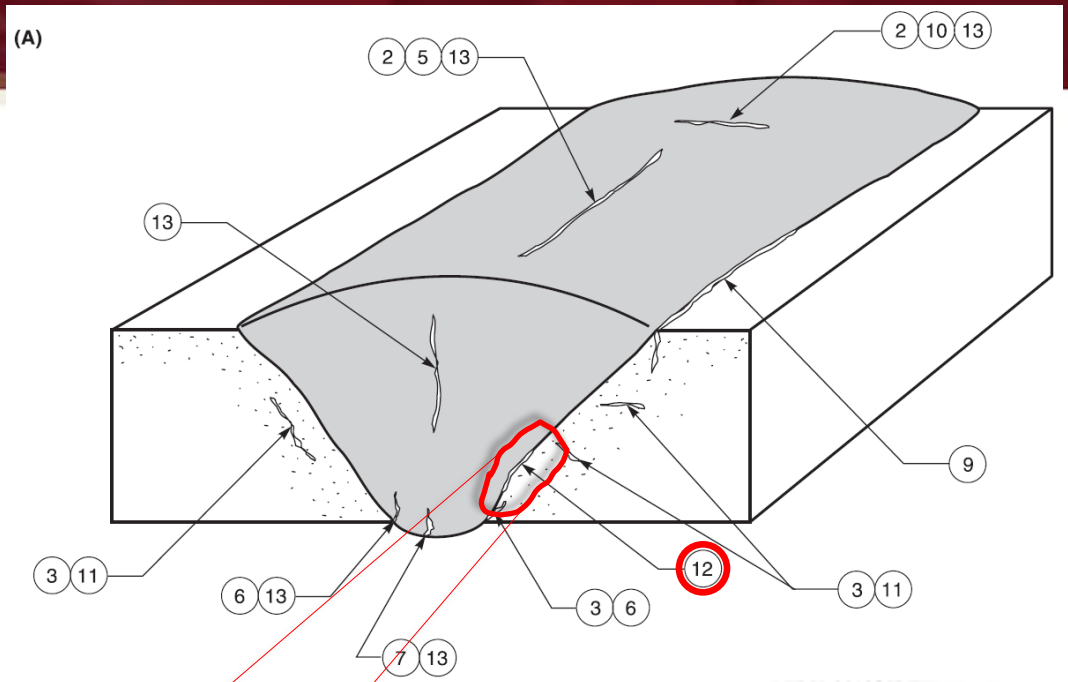

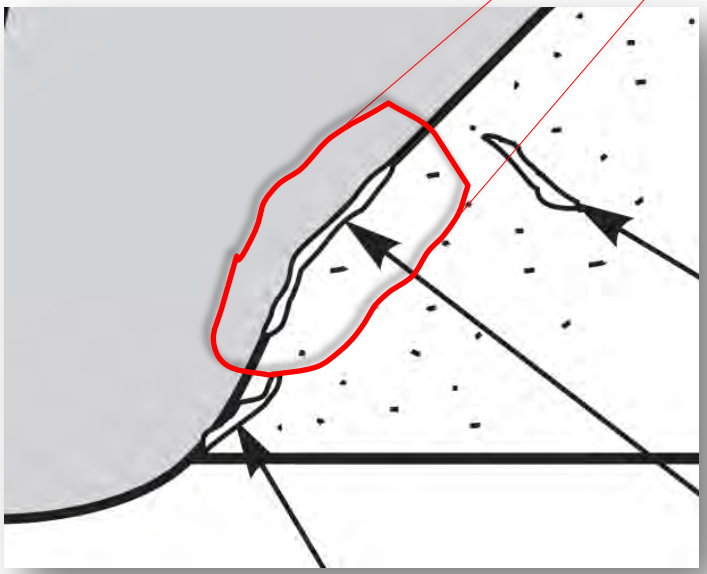

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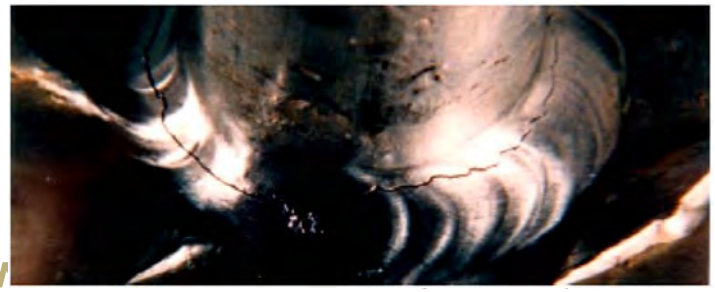
Causes

- Hydrogen cracking has been one of the biggest problems when welding of armor steels
- Cracks are delayed since hydrogen does not become entrapped above 200^{0}C (392°F)
- Depending on the rate of hydrogen diffusion, the delay of the cracks can change
- Diffusion rates depends on the steel's microstructure and temperature, lower temperatures means slower diffusion

Causes

Hydrogen Cracking

- Is the process by which various metals, including high-strength armor steels, become brittle and fracture following exposure to hydrogen
- Begins during the welding procedure where there are elevated temperatures
- Usually happens 24-48 hours after the weldments are at ambient temperatures



Causes:
Conditions of Hydrogen Embrittlement

Three Conditions of Hydrogen Cracking

- The presence of hydrogen
  - Delivered by gases released from the electrode coating or flux, and some from the atmosphere
- A susceptible microstructure
  - Determined by the chemistry of the electrode and base metal and the welding parameters
  - Martensitic microstructures are above ≈35 HRC are susceptible
    - All current armor steels are martensitic
- Tensile stress
  - Caused by thermal expansion and contraction of the weld as it is deposited, aligning the base materials, and handling
  - Martensitic structures have inherent residual stresses due to the 4% Volume expansion.

Electrodes and Flux

- Shielding gas also contains hydrogen from organic elements in the coating and moisture
- Different electrodes causes different hydrogen content in the weld metal
- SMAW electrodes produce the widest range of hydrogen content
- GMAW electrodes produce the smallest range of hydrogen content
- Electrodes must be stored and handled properly

Weld Metal Hydrogen Designations

Hydrogen Designation	Maximum Average Content, mL(H_2)/100g	Examples
High	>15	Cellulosic electrodes, flux cored electrodes
Medium	10	Basic electrodes, flux cored electrodes, solid wire electrodes
Low	5	Basic electrodes, flux cored electrodes, solid wire electrodes
Very Low	3 to 5	Baked basic electrodes, solid wire electrodes
Ultra Low	≤3	Baked basic electrodes, solid wire electrodes

Basic vs. Low Hydrogen Electrodes

- Basic Electrodes

  - Most common type of electrode

  - Typical levels of hydrogen found in welds created using this type of electrode is 5ml/100g

- Low Hydrogen Content Electrodes

  - Typical levels of hydrogen found in welds created using this type of electrode is 3ml/100g

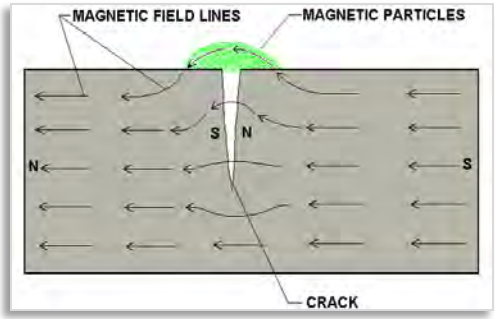
  - Electrodes are packed in hermetically sealed containers. This keeps moisture out for extended periods of time

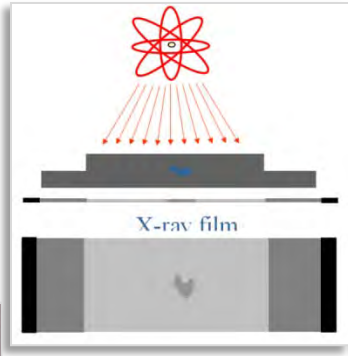
Ceramic Weld Backings

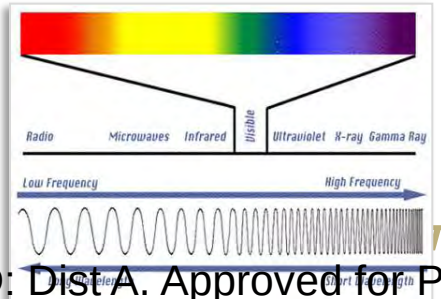
- Used to reduce costly gouging and grinding
- Ceramics are absorbent to liquids and other materials
- Improper handling may result in moist ceramic backings releasing hydrogen into the weldments

Inspection

- 48 hour holds
  - AWS D1.1 : ASTM 514, ASTM517
  - Ground Combat Vehicle Weld Code (GCVWC) :ASTM 514, ASTM517
  - MIL-DTL-46100, MIL-DTL-12560J, & MIL-DTL-32332
- Inspection Methods
  - Visual
  - PT
  - MT
  - UT
  - RT
- No cracks are allowed on Armor!!!







Prevention

- Reduce Source of H_2
- Low Hydrogen Processes
  - SMAW
  - FCAW
- Electrode Selection
  - Solid Core Wires or Metal Core
  - Non- Low Hydrogen Rods
- Electrode Storage
  - Rod ovens
  - Room temperatures/dew point control
  - Time spent in atmosphere
- Minimize causes of residual stresses
  - Fixture Gaps
  - Control Heat Input

Conclusion

- Materials and Types for Cracking
  - Hot Cracking
  - Cold Cracking
- Types of cracks
- Causes
  - Hydrogen
  - Electrode Selection
  - Electrode Storage
- Inspection Methods
  - PT, UT, RT, MT
- Preventions
  - Hydrogen
  - Electrode Selection
  - Electrode Storage

Question???

Any Question???

TARDEC - RDTA-EN / Materials, Environmental and Corrosion Team